CODAR VIEWER - A V2V COMMUNICATION AWARENESS DISPLAY

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Abstract
The CODAR System is a simulation and visualization toolbox for vehicle-to-vehicle communication. In this paper, we introduce the visualization component, the CODAR Viewer, as context information display. It visualizes communication, creates awareness and provides situation information. Visualized vehicle-to-x (V2X) communication data provides additional information, increasing safety and allowing more informed driving decisions if adequately presented to the driver with respect to the current traffic situation and the driver's free mental capacities.

1. Introduction

Modern vehicles have a significant number of **intra-vehicle** communication systems and busses and hundreds of sensors connected, delivering information at high data rates. The sensor density in modern cars is comparatively high as in pervasive computing environments. Interconnecting sensor-equipped vehicles enables novel types of applications. The idea of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication is to collaboratively share a subset of this information to increase road safety, efficiency and comfort.

The *CODAR* System (***C***ooperative ***O***bject ***D***etection ***A***nd ***R***anging) is a toolkit combining

- simulation environment (e.g. to add virtual vehicles to a real traffic situation),
- visualization components (e.g. to visualize the situation in the vehicle to the driver, or showing a global traffic management view, or V2X communication messages, ...), and
- algorithm toolbox (e.g. for detecting a hazardous situation, test V2X supported adaptive cruise control, ...).

It allows the developer of V2X applications to test and simulate communication, to test algorithms, e.g. on HMI adaption to deliver situated warning messages to the driver or on how to display other vehicles to the driver, and to visualize traffic scenarios. The *CODAR System* is one of the first frameworks supporting developers in the area of V2X research. The versatility of the *CODAR System* allows the framework to be used as global traffic monitoring system, as network analyzer, or as as in-vehicle information display. In this paper, we slightly focus on the last application scenario, the *CODAR Viewer* as information visualization component for the driver.

Many applications of V2X communication work on system level such as pre-crash sensing or only forward information to the driver in special situation e.g. warning messages of a broken down vehicle. The *CODAR Viewer*, as presented in this paper, is an additional source of information for the driver, equal to e.g. a look over the shoulder. The situation and context display enables the driver to build up an increase situation awareness and consequently a better traffic overview.

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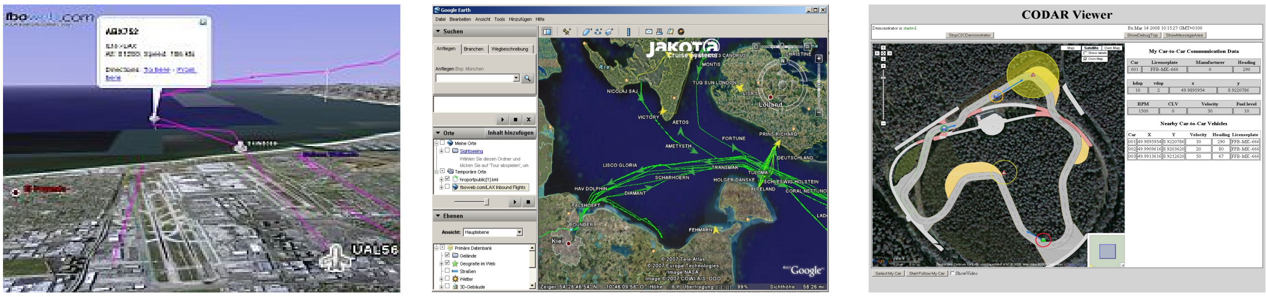


(a) Real time flight tracking as Google Earth application

(b) Geocoded Ships and their trajectories

(c) CODAR Viewer - Traffic Management Center View

Figure 1. Geocoding applications visualize complex information, make them accessible and thereby create awareness for abstract data. Access to the information is made faster by good visualization.

2. Related Work

V2X communication visualization is dynamic, mobile, and ad-hoc geocoding of information with additional situation modeling. It connects time information and geographic location with physical information such as the vehicle's internal and external state, the driver's awareness or environmental features such as temperature or road conditions. The result is increased situation- and context awareness for traffic participants. The architecture of the *CODAR* system integrates into our research on situation aware driver assistance systems [4].

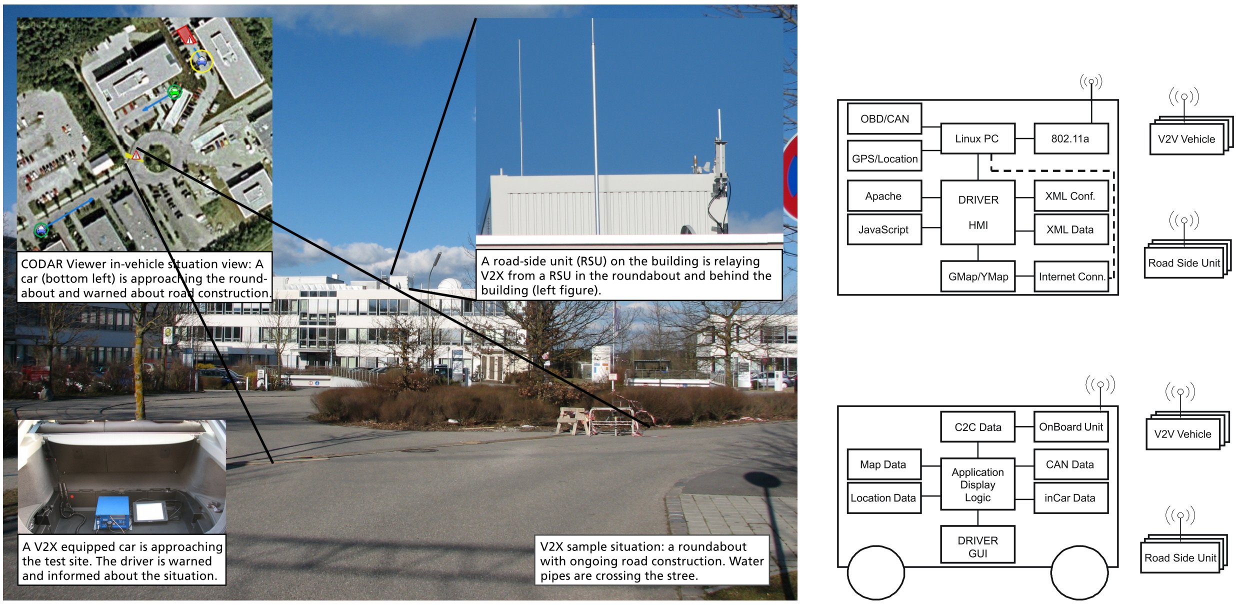
Scholl et al. [1] geocode static sensor nodes as web services with low update rates using Google Map as display engine. The sensor information is collected in local cells and made available by network-to-network bridges on the internet as web service. The final application provides the user an absolute global information view, aggregating all present information.

The information display shown in Fig. 1 (a) is a low-latency application which displays flight information [2], centrally collected by a server querying ground stations. The *CODAR Viewer* is mainly intended to show locally available information based on V2X communication information with nearby mobile and static nodes (vehicles and road-side units (RSUs)), however any arbitrary source of information, e.g. from WANs, can be incorporated.

The geocoding application shown in Fig. 1 (b) shows a high-latency ship tracking application [5]. As in our *CODAR Viewer*, otherwise unacessible information is visualized. In contrast to our system, this information is not generated by node-to-node communication, but by a central instance. However, the *CODAR Viewer* can merge information e.g. from RSUs with fixed WAN connection and display the overall traffic situation as needed in traffic management centers (Fig. 1 (c)).

Both systems [1, 2] use an approach different to our application. However, they show how much more information can be mediated by properly visualizing complex and otherwise unaccessible data. This is an intention we want to extend to V2X communication with the *CODAR Viewer*.

Compared to personal navigation systems which also track individual positions and are able to display information about near-by items (point-of-interest notification), the data displayed on the *CODAR Viewer* is updated more dynamic by other traffic participants and RSUs. It shows real-time situation information. While dynamic information could be added using e.g. a point-to-point 3G mobile internet connection, the V2X data is originating from a dedicated V2X communication infrastructure using unicasts, broadcasts and geocasts.



(a) CODAR Viewer System: In-Vehicle System Visualization, Road-Side Units, On-Board Unit and Traffic Situation

(b) V2X On-Board Unit: Current and General Setup

Figure 2. The *CODAR Viewer* awareness display for V2X communication comprises information applets providing network analyzer, awareness display and self-information functionality to the driver.
The current CODAR Viewer (top right) setup consists of a Linux-based PC with GPS, CAN and OBD interfaces and a GUI on a touchscreen monitor. IEEE 802.11a WLAN simulates IEEE 802.11p networking hardware on a similar frequceny until the final communication hardware is available. The bottom right figure shows the envisioned system setup that e.g. also comprises offline maps.

3. CODAR Viewer

The *CODAR Viewer*, as depicted in Fig. 1 (c) and Fig. 2 (a), is a versatile application. It is a network analyzer, an awareness display, and a self-information display (right part). It can be used in real-time mode, as simulator-only front end or in combination.

The *CODAR Viewer* as radar-like visualizer for V2X communication conveys information to the driver and provides assistance in situations that are not supported by other technologies. While radar or night vision can improve the sight of the driver, they cannot 'see' around the curve or behind a hill top or detect a vehicle quickly approaching a crossing in the city. **Visualized** V2X communication complements existing technologies in a great variety of situations. Fig. 2 (a) depicts the in-vehicle application. The vehicle are augmented with a vector, directly visualizing speed and heading of vehicles. The circles around the vehicles visualize the horizontal dilution of precision of the underlying positioning system. Road features that require special attention are overlaying the map view with their extent such as circles or polylines.

The *CODAR Viewer* supports the driver in several ways. It creates **individual awareness**. The driver knows more about **his** imminent situation and can make more informed decisions. The application supports **cooperative awareness**. The driver now has information about the context of **other road users**. This supports a better understanding, e.g. why there is a traffic jam and that it only goes on for half a mile or that it does not make sense to overtake a truck as there is another one close which cannot be seen from the vehicle's current position.

Due to the ability of visualizing other cars and consequently their drivers as well as the own vehicle in their *CODAR Viewer*, privacy concerns might arise. This is currently an open research topic. It is envisioned that these issues will be addressed by the underlying communication infrastructure. The publicly visible vehicle ID for example can be changed by the V2X system on demand to prevent tracking, e.g. as part of a Virtual ID (VID) system. As Krumm et al. [3] proved that GPS traces can actually reveal much more information about an individual than the mere location points, even if the origin is artificially obscured.

The prototype hardware for the in-vehicle *CODAR Viewer* is depicted in Fig. 2 (b, bottom right). Fig. 2 (b, top right)shows the general system architecture. A Linux PC with GPS receiver and CAN and OBD interface presents information on either a Google or Yahoo map to the driver via a local web server. The map data is acquired by an additional mobile broadband connection. The information is processed by the algorithm toolbox component and presented to the driver on an additional screen in the vehicle. The physical layer used in European V2X communication, IEEE 802.11p WLAN, is currently simulated by an IEEE 802.11a Atheros Wi-Fi network card using a similar frequency as with the final system. The card supports ad-hoc networking with other IEEE 802.11a systems. The physical system currently used uses one car on-board unit and one road-side unit. Other vehicles are simulated and integrated in the visualization.

4. Future Work and Outlook

The CODAR Viewer for the driver runs completely integrated on an in-vehicle display, like a fixed navigation unit with touch screen display. The application will allow both online and offline maps, removing the necessity for an additional broadband connection. Localized maps and map updates will use the V2X communication link. The general system overview of the next iteration using a specialized V2X on-board unit is depicted in Fig. 2 (a) (bottom left). The next version will additionally allow situated warning and information overlays on the map display. The awareness display will be overlayed with driver assistance information and warnings and alerts and thereby complement installed safety and information systems.

Currently, range and frequency tests are conducted at the test site. Application and visualization are subject to ongoing user studies.

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